Chapter 3. ENVIRONMENTAL SETTING

3.1 General

Pacific herring, *Clupea pallasi*, are found throughout the coastal zone from northern Baja California on the North American coast, around the rim of the North Pacific Basin and Korea on the Asian coast (Outram and Humphreys 1974, Hart 1973). In California, herring are found offshore during the spring and summer months foraging in the open ocean. Beginning as early as October and continuing as late as April, schools of adult herring migrate inshore to bays and estuaries to spawn. Schools first appear in the deep water channels of bays to ripen (gonadal maturation) for up to two weeks, then gradually move into shallow areas to spawn. The largest spawning aggregations in California occur in San Francisco and Tomales bays. San Francisco Bay is also near the southern end of the range for Pacific herring (Miller and Schmidtke 1956).

Spawning occurs in the intertidal and shallow subtidal zones. Males release milt into the water column while females extrude adhesive eggs on a variety of surfaces including vegetation, rocks, and man-made structures such as pier pilings, boat bottoms, rock rip-rap, and breakwater structures. Embryos (fertilized eggs) typically hatch in about ten days, determined mainly by water temperature. Larval herring metamorphose into juvenile herring in about ten to twelve weeks. In San Francisco Bay, juvenile herring typically stay in the Bay through summer, and then migrate out to sea. Where juvenile herring migrate to once they leave the bays and estuaries is not known or understood.

Most of the herring fisheries occur during the spawning season. The roe herring gill net fisheries catch herring as they move into the shallows to spawn when the eggs are ripest. The primary product from this fishery, *kazunoko*, is the sac roe (eggs) in the females which are processed and exported for sale to Japan. California's roe herring fisheries occur in the Crescent City Harbor area, Humboldt Bay, Tomales Bay, and San Francisco Bay.

The San Francisco Bay herring eggs-on-kelp fishery suspends Giant kelp, *Macrocystis pyrifera*, from rafts for herring to spawn on in shallow water areas.

The kelp is harvested near the Channel Islands and/or in Monterey Bay and then transported to San Francisco Bay. The product of this fishery is the egg-coated kelp blades that are processed and exported to Japan. This product, *komochi* or *kazunoko kombu*, is served as an appetizer typically during New Year's celebrations

The only ocean fishery for herring in California occurs during the non-spawning season in Monterey Bay. Landings from this fishery enter the aquarium food and bait markets. Small fisheries for fresh fish are also permitted during the non-spawning season in Tomales Bay and San Francisco Bay.

Herring are a food source for many species of birds, fish, invertebrates, and mammals. Predation is particularly high during spawning when adult fish and eggs are concentrated and available in shallow areas. Predation by birds and fish during the egg stage, when eggs are deposited in the intertidal and shallow subtidal zones, is a significant cause of natural mortality for herring.

The roe herring fishery in California has been intensively regulated since its inception in 1973, at first by the California State Legislature, then by the Fish and Game Commission (Commission). Department of Fish and Game (Department) estimates of the spawning population biomass have provided a critical source of information used for establishing fishery quotas to control the harvest of herring and provide for the long-term health of the herring resource. A thorough description of the environmental setting is provided in Chapter 3 of the 1998 Final Environmental Document (FED), which includes Pacific herring life history, ecology, status of stocks and fisheries at that time, and biological and environmental descriptions of herring fishery locations (Crescent City area, Humboldt Bay, Tomales Bay, San Francisco Bay, and Monterey Bay).

3.2 Spawning Population Estimation Methods

Estimates of spawning biomass are made by the Department in Tomales and Humboldt bays using spawn deposition surveys (refer to sections 3.4 and 3.5 below). For San Francisco Bay, the Department estimated spawning biomass using spawn deposition surveys from 1973-1974 through 1988-89

seasons. From the 1990-91 through 2001-02 seasons, the Department estimated spawning biomass from a combination of spawn deposition and hydroacoustic surveys for San Francisco Bay. Beginning with the 2003-04 season, the Department reverted to using the spawn deposition surveys alone for biomass estimation. In addition to the estimates of spawning biomass, the Department collects fishery independent age composition data from the population, as well as fishery dependent age composition data from the commercial catch. All of the information collected by the Department, including ocean conditions, is used in annual population assessments.

3.3 Status of the San Francisco Bay Spawning Population

The 2005-06 spawning biomass estimate is 145,054 tons (including catch), a 146 percent increase over last season's estimate of 58,934 tons (Figure 2.2). It is the second consecutive spawning biomass estimate to exceed the 27-year long-term average, 55,278 tons, since the 1996-97 season, following seven consecutive seasons of below-average spawning biomass. The spawning biomass estimate for this season is the largest recorded estimate in the history of the roe herring fishery. There were 23 spawning events this season, over twice the amount of an average season (11 spawning events). The combined area for all spawns covered an estimated 37,360,505 m^2 and was 313 percent greater than the historical average (9,043,509 m^2).

The first recorded spawn of the season occurred on December 1, 2005, and the latest spawn occurred on April 2, 2006 (Table 3.1). Spawning events were recorded throughout San Francisco Bay, from as far north as the Marin Islands in San Rafael Bay to Oyster Pt. in the south bay. This season's vegetation survey revealed a dramatic increase of *Gracilaria spp.* in Richardson Bay. Density values for *Gracilaria spp.* in Richardson Bay were slightly greater this season (2.33 kg/m) than the previous season (2.28 kg/m), but the extent of the area covered by *Gracilaria spp.* was much larger. A substantial amount of *Gracilaria spp*. was again located in the subtidal area south of Candlestick Point for the second consecutive season.

Table 3.1. 2005-06 Pacific Herring Spawning Biomass Estimates for San Francisco Bay
Spawns recorded as of 4/14/2006; all weights in short tons

Wave Number	Approx. Spawn Date(s)	Location(s)	Spawn Escapement Estimate	Catch	Spawning Biomass Estimate
1	December 1-3, 2005	Candlestick/Hunters Pt.	1,940		1,940
2	December 9-10, 2005	Richardson Bay	6,526		6,526
3	December 11-12, 2005	Candlestick/Hunters Pt	1,080		1,080
4	December 25, 2005	Candlestick/Hunters Pt	1,659		1,659
5	December 29-30, 2005	Richardson Bay	16,970		16,970
6	January 7-9, 2006	Oyster Pt/Sierra Pt	8,655		8,655
7	January 6-8, 2006	Richardson Bay	20,773	81	20,854
8	January 12-15, 2006	Richardson Bay	8,185		8,185
9	January 24-26, 2006	Richardson Bay	9,052		9,052
10	January 24-26, 2006	Belvedere Cove	176		176
11	January 24-26, 2006	Candlestick to SF Waterfront	5,652	434	6,086
12	February 3, 2006	Richardson Bay	30,297	1	30,298
13	February 8-13, 2006	Richardson Bay	1,607		1,607
14	February 13, 2006	Paradise	25	80	105
15	February 20, 2006	Richardson Bay	2,100		2,100
16	February 20, 2006	San Quentin	1,437	148	1,585
17	February 20, 2006	Marin Islands	805		805
18	February 25, 2006	Richardson Bay	1,071		1,071
19	March 3, 2006	Richardson Bay	24,413		24,413
20	March 5-6, 2006	Belvedere Cove	28		28
21	March 5-6, 2006	Kiel Cove	327		327
22	March 16-17, 2006	Richardson Bay	1,038		1,038
23	April1-2, 2006	Richardson Bay	493		493
Totals			144,309	744	145,053

The spawning season started off slowly with no recorded spawns in the month of November, but quickly gained momentum at the beginning of December. Spawning was consistent between December and March, averaging almost six spawning events per month. A sizeable spawn was even recorded in the month of April. The majority of spawning events this season were located in the subtidal, versus intertidal, zone, and focused in areas with high concentrations of *Gracilaria spp*. (i.e. Candlestick area and Richardson Bay).

Continuing the trend of recent years, the majority of spawning occurred in the North-Central Bay (Pt. Bonita to Pt. San Quentin, Pt. San Pablo to the Bay

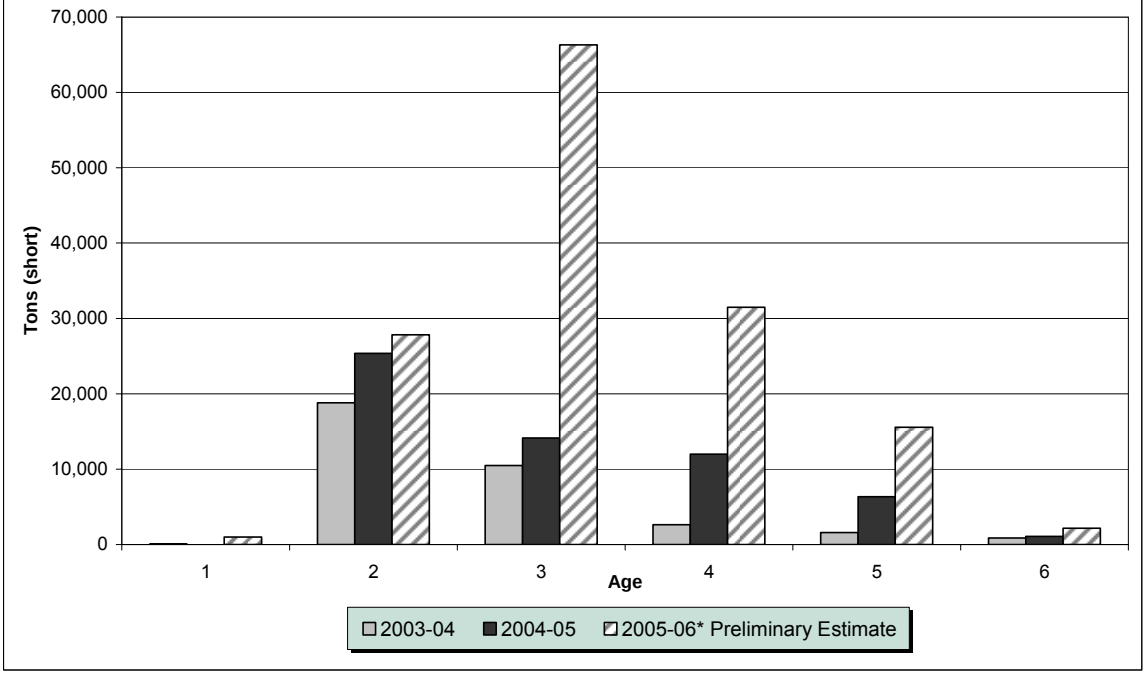
Bridge). Eighty-eight percent of the 2005-06 season total spawn escapement biomass occurred in North-Central Bay, with 85 percent of the season's total occurring within Richardson Bay, primarily in the subtidal beds of eelgrass and *Gracilaria spp*. A total of twelve spawns occurred in Richardson Bay this season and at times spawning seemed almost continuous. However, spawning events were distinguished by determining egg development and observing shifts in the areas spawned upon over time (i.e., from the main subtidal bed to the cross channel beds). North-Central Bay spawning activity also included a spawn at the Marin Islands and Pt. San Quentin, which included spawn along the shoreline from northwest of the Marin Rod and Gun Club pier to the west end of San Quentin Prison. This was the second spawn of measurable size documented at Pt. San Quentin, and the first documented spawn at the Marin Islands in the 33-year history of the spawn survey.

The current age composition indicates above average to strong recruitment of 2- and 3-year-old herring. The estimated number of two-year-olds was 72 percent higher than the long-term mean and approximately 14 percent higher than the 2004-05 season estimate (Table 3.2). The estimated number of 3-year-olds was the highest ever recorded, approximately 264 percent above the long-term mean and 116 percent higher than the 2004-05 season estimate. There were also significant increases in the numbers of 4-, 5-, and 6-year-old herring (76, 173, and 74 percent by number respectively from the 2004-05 season). The estimated numbers of 4- and 5-year-olds were above average; however, the numbers of 6-year-olds were below the long-term mean. Although the numbers of six-year-old herring increased from the 2004-05 estimate, herring older than six years remain nearly absent from the population. The greatest increase in spawning biomass by age group appears to be the three-year-old cohort (Figure 3.1) from the 2003 year class.

Table 3.2 Estimated Numbers (x 1,000) of Herring-at-Age in the San Francisco Bay Spawning Population, 1982-83 to present																		
	Age and Percent Composition																	
Season	**1**	**%**	**2**	**%**	**3**	**%**	**4**	**%**	**5**	**%**	**6**	**%**	**7**	**%**	**8**	**%**	**9**	**%**	**Total**
82-83	[a]	N/A	87,908	14.8	149,971	0.3	182,936	30.7	118,040	19.8	30,478	5.1	17,177	3	8,121	1.4	797	0.1	595,428
83-84	[a]	N/A	332,699	56.6	69,654	0.1	92,565	15.8	73,840	12.6	17,306	2.9	1,168	0	117	0	0	0	587,349
84-85	[a]	N/A	184,695	38.7	190,998	40	46,613	9.8	22,153	4.6	25,914	5.4	6,652	1	688	0.1	0	0	383,033
85-86	[a]	N/A	162,422	32.4	160,613	32.1	126,535	25.3	26,790	5.3	16,038	3.2	7,752	2	717	0.1	182	0	501,049
86-87	[a]	N/A	168,962	29.2	194,365	33.6	134,528	23.2	64,598	11.2	9,182	1.6	6,175	1	1,065	0.2	246	0	579,121
87-88	[a]	N/A	233,193	30.6	292,508	38.3	136,604	17.9	66,494	8.7	25,337	3.3	5,027	1	3,939	0.5	0	0	763,102
88-89	[a]	N/A	146,525	25.8	222,058	39	139,906	24.6	44,435	7.8	12,310	2.2	3,030	1	534	0.1	0	0	568,798
89-90	[a]	N/A	294,631	37.6	237,377	30.3	136,248	17.4	84,361	10.8	23,970	3.1	6,572	1	0	0	0	0	783,159
90-91																			
91-92	1,356	0.3	13,666	3.0	126,016	28	206,930	45.2	82,870	18.1	23,764	5.2	3,490	1	0	0	0	0	458,092
92-93	0	0	48,925	20.5	50,398	21.1	79,045	33.1	51,713	21.7	8,642	3.6	0	0	0	0	0	0	238,723
93-94	11,485	2.6	22,403	5.1	134,870	31	160,335	36.9	63,331	14.6	25,926	6	4,808	1	355	0.1	0	0	423,513
94-95	2,276	0.5	39,363	9.0	236,783	54.1	94,833	21.7	42,850	9.8	18,223	4.2	3,196	1	0	0	0	0	437,524
95-96	3,142	0.3	483,164	38.9	359,357	29	282,069	22.7	81,768	6.6	28,904	2.3	1,687	0	0	0	0	0	1,240,091
96-97	1,184	0.1	290,497	29.1	359,459	36	183,370	18.4	120,029	12	33,098	3.3	8,935	1	270	0	0	0	996,842
97-98	42	0	45,092	17.2	129,411	49.3	65,637	25	18,724	7.1	2,259	0.9	1,430	1	0	0	0	0	262,595
98-99	1,931	0.4	256,816	52.0	54,306	11	114,835	23.2	56,915	11.5	9,729	2	558	0	978	0.2	[b]	0	496,068
99-00	1,440	0.4	103,490	30.4	154,260	45.3	48,150	14.1	29,000	8.5	4,310	1.3	0	0	0	0	[b]	0	340,650
00-01	255,158	36	178,401	35.4	185,748	36.9	65,555	13	24,267	4.8	126	0	0	0	0	0	0	0	709,255
01-02	5,788	1.5	157,182	39.6	138,752	35	75,088	18.9	15,383	3.9	4,265	1.1	152	0	0	0	0	0	396,610
02-03																			
03-04[c]	2,473	0.5	328,257	65.5	122,072	24.3	26,641	5.3	14,848	3	7,225	1.4	0	0	0	0	0	0	501,516
04-05[d]	0	0	287,298	33.1	360,741	41.6	166,538	19.2	44,684	5.2	8,367	1	0	0	0	0	0	0	867,628
05-06	*32,336*	*2.1*	*327,320*	*20.9*	*780,196*	*49.7*	*293,094*	*18.7*	*121,980*	*7.8*	*14,568*	*0.9*	*0*	*0*	*0*	*0*	*0*	*0*	*1,569,493*
Mean	**22,758**	**3.2**	**190,587**	**30.2**	**214,087**	**32.1**	**129,912**	**21.8**	**57,685**	**9.8**	**15,906**	**2.7**	**3,537**	**0.6**	**763**	**0.1**	**61**	**0.0**	**635,296**

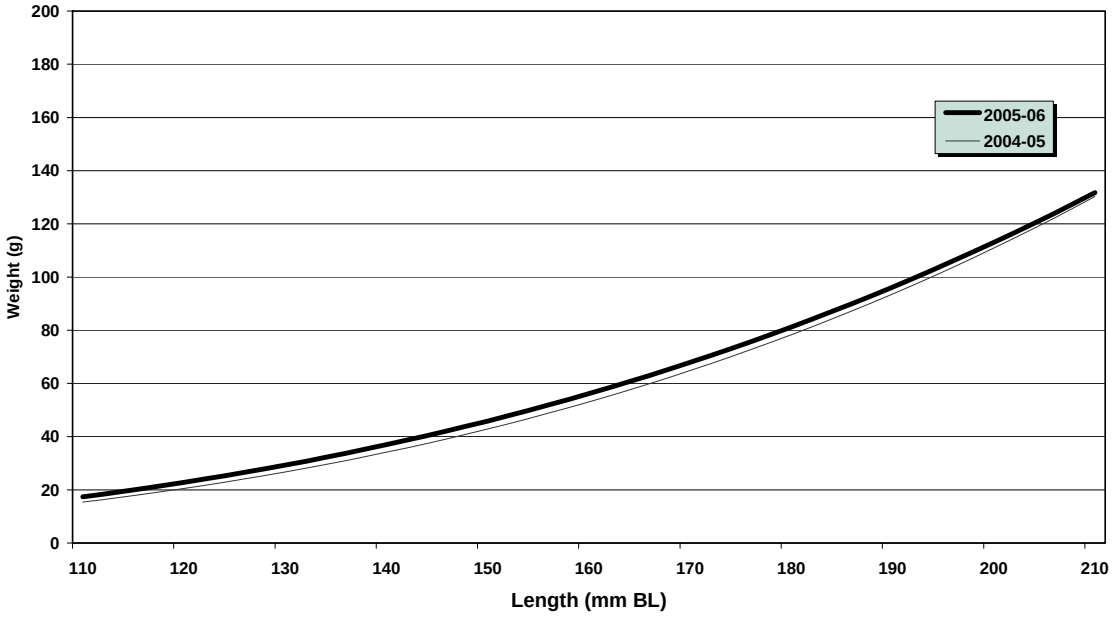
Note: 1990-91 season was not included due to incomplete data set for that season; 2002-03 season spawning biomass estimate unresolved.
[a] 1-year-olds were not estimated, [b] 9-year-olds were not estimated, [c] includes corrected estimated number of two-year-olds, [d] no 1-year-olds were were sampled in spawning condition

Figure 3.1 San Francisco Spawning Biomass by Age Class: Comparison Between 2003-04, 2004-05, and 2005-06



Length weight regression analysis of data taken from ripe herring sampled this season with research gear (midwater trawl) indicates that herring were slightly heavier in weight for a given length compared to the 2004-05 season (Figure 3.2). This indicates there was a slight improvement in the condition of herring after the 2004-05 El Niño. Additionally, samples taken from the commercial gill net fishery also indicate herring were in better condition compared to the previous season. The mean length of commercial gill net samples for the 2004-05 season was 191 millimeters (mm) Body Length (BL) and weights averaged 98 grams (g). This season, the average length of the commercial catch decreased to 188 mm BL and, average weight of sampled fish declined to 97 g. Despite being 3 mm smaller on average, commercially caught herring this season were only a gram lighter which indicates herring may have been in better condition. A decline in the average size was not unexpected due to the change in minimum mesh size from 2 1/8 inches to 2 inches this season. The mean length of commercially caught San Francisco Bay herring this season

Figure 3.2 Length Weight Relationships of Research Gear Caught San Francisco Bay Ripe Herring: 2004-05 and 2005-06 Seasons



(188 mm) is similar to the mean length (189 mm) of commercially caught herring during the Tomales Bay 2 inch experimental mesh study period (2000-01 to present). Both bays currently have a relatively similar age structure that lack older herring.

Although the annual estimated spawning biomass is 146 percent higher than the 2004-05 season, and 4-, 5-, and 6-year-old sized herring increased a total of 29,469 tons from the previous season (Figure 3.1), the commercial catch, while larger than last season, has remained quite low. A number of factors are most likely responsible for this result. This season's spawning population was dominated by younger fish; approximately 71 percent by number of the spawning biomass was composed of 2- and 3-year-old sized herring. In addition to the large numbers of young fish, a majority of the spawning took place in Richardson Bay, an area closed to the commercial fishery. Also, most of the spawning was subtidal, with only a small portion of intertidal spawning along the San Francisco waterfront providing the majority of the season's catch. The result was an extremely low exploitation rate (0.5 percent) of the spawning population.

In summary, because of the record spawning biomass there was a significant increase in the number of fish from age 4 through 6 from the 2004-05 season. This increase and the apparent strong recruitment of age 3 fish are both signs of improvement in the San Francisco Bay spawning population. If the population continues to persist at a high level, and the different age classes continue to increase in number, the outlook for the stock to rebuild and improve its age structure is good. However, the continuing trend of below average numbers of six-year-old herring and absence of older herring continue to be a cause for concern. This truncation in the age structure since the 1997-98 season and apparent reduction in size at age provide cause for continued conservative management measures for the stock.

3.3.1 San Francisco Bay Herring Young of the Year (YOY)

Pacific herring young-of-the-year (YOY) are commonly caught by the Department's Central Valley Bay-Delta Branch San Francisco Bay Study (SFBS) during the spring and summer of each year. The SFBS conducts surveys to determine the abundance and distribution of invertebrates and fishes in the Western Delta and San Francisco Bay. Stations are sampled using a variety of research nets and other equipment, including a midwater trawl that is towed obliquely through the water column to capture species inhabiting varying depths. An index of abundance is calculated for YOY Pacific herring (Interagency Ecological Program Technical Report 63).

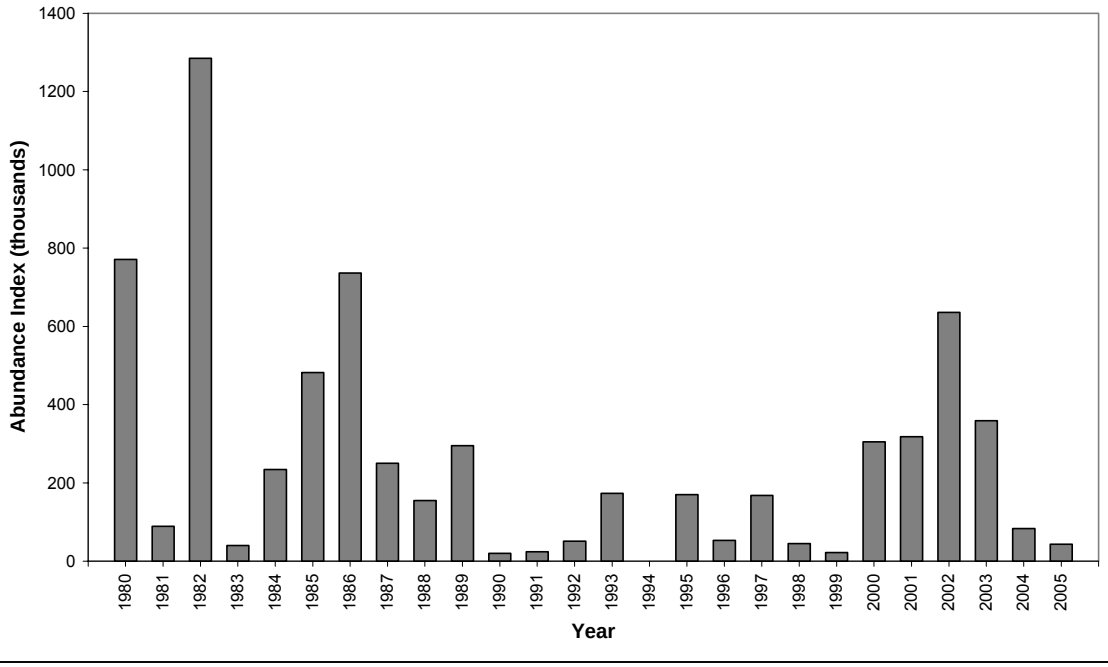
The herring YOY abundance index for 2005 shows a decline to pre-2000 levels (Figure 3.3). The strength of the YOY indices for the 2000 to 2003 year classes indicated favorable environmental conditions for YOY survival and growth within San Francisco Bay; however, the low indices for 2005 may reflect unfavorable conditions relative to growth. The low index may indicate poor recruitment of this cohort as it recruits to the spawning population in 2007-08 and 2008-09 seasons as 2- and 3-year-olds. However, there is no strong predictive relationship, historically, between the YOY abundance index and the subsequent numbers of two and three year-old herring that return to spawn. Survival to first

reproduction is affected by a number of factors during the first two to three years of life, including predation, food availability, and competition.

3.4 Status of the Tomales Bay Spawning Population

The Tomales Bay 2005-06 spawning biomass estimate is 2,033 tons, a 45 percent decline from the 2004-05 biomass estimate of 3,686 tons. The spawning biomass estimate is 48 percent less than the 14-season average of 3,889 tons (i.e., since the fishery was re-opened for the 1992-93 season). It is not uncommon for the spawning biomass population in Tomales Bay to fluctuate from season to season (Table 3.3). The spawning biomass estimate for the 2005-06 season remained below-average and was the second consecutive season of decline. The declining spawning biomass could be caused by separate or combined effects from two anomalous events that created unfavorable environmental conditions. The first, an unusual warm water event off of Northern California, Oregon, and Washington occurred last spring and

Figure 3.3 San Francisco Bay herring young-of-the-year abundance indices: 1980-2005



summer. This event was not considered an El Niño, in which warm water typically progresses northward from the equatorial Pacific. In this event, warm offshore water moved onshore decreasing coastal upwelling in the nearshore environment. This effect may have created unfavorable oceanic conditions for herring, resulting in temporal effects in the food web, competition, predation, and altered migration patterns. Second, the extraordinary amount of rainfall this season greatly increased the freshwater in-flow to Tomales Bay. The reduced salinities in the bay, lead to poor spawning conditions and displacement of spawning herring to areas with more favorable conditions.

There were four major spawning events during the 2005-06 season totaling 2,014 tons of spawning escapement. Seven different spawning areas were utilized from November through January. The location of spawning events showed a similar pattern to previous seasons, as spawning was confined to the southern half of Tomales Bay; however, the timing and magnitude of spawning changed this season.

It was the second time since the 1999-2000 season that December spawning escapement did not account for at least 50 percent of the season's spawn escapement, as larger spawn events occurred in January. The spawning escapement total for January was above average for the 14-year period after the Tomales Bay fishery was re-opened for the 1992-93 season, but monthly totals for November, December, February, and March were below average.

Eelgrass (*Zostera marina)* and *Gracilaria spp.* resources in Tomales Bay appeared healthy and provided ample spawning substrate suitable for herring. Environmental conditions in Tomales Bay (i.e., freshwater inflow and salinity) may be a factor in the decline in spawning biomass this season. The high amount and duration of rainfall in Tomales Bay maintained low salinity levels for prolonged periods that may have created poor spawning conditions and deterred more herring from utilizing Tomales Bay as a spawning area. A similar event occurred in the 1997-98 season, when large amounts of rainfall reduced bay salinities and appeared to deter herring from entering Tomales Bay to spawn.

Table 3.3 Season Spawning Biomass for Tomales Bay

Season	Spawn Escapement (tons)	Catch (tons)	Percent Catch (Exploitation Rate)	Spawning Biomass (tons)
1972-73 [a, 1]	---	598	---	---
1973-74 [a]	6,041	521	7.9%	6,562
1974-75 [a]	4,210	518	10.9%	4,728
1975-76 [b]	7,769	144	1.8%	7,913
1976-77 [b]	4,739	344	6.7%	5,083
1977-78 [b]	21,513	646	2.9%	22,163
1978-79 [c, 1]	---	448	---	---
1979-80 [c]	5,420	603	10.0%	6,023
1980-81 [c]	5,128	448	8.0%	5,576
1981-82 [c]	6,298	851	11.9%	7,149
1982-83 [c]	10,218	822	7.4%	11,040
1983-84 [c]	1,170	110	8.5%	1,280
1984-85 [d]	6,156	430	6.5%	6,586
1985-86 [d, 2]	435	771	12.8%	6,000
1986-87 [d]	4,931	867	14.9%	5,798
1987-88 [d]	1,311	750	36.4%	2,061
1988-89 [d]	167	213	56.0%	380
1989-90 [e]	345	0	0.0%	345
1990-91 [e]	779	0	0.0%	779
1991-92 [e]	1,214	0	0.0%	1,214
1992-93 [f]	3,857	222	5.4%	4,079
1993-94 [f]	2,244	219	8.9%	2,463
1994-95 [f]	3,704	275	6.9%	3,979
1995-96 [f]	1,704	355	17.2%	2,059
1996-97 [f]	1,288	222	14.7%	1,510
1997-98 [f]	586	0	0.0%	586
1998-99 [f]	4,015	54	1.3%	4,069
1999-00 [f]	1,969	42	2.1%	2,010
2000-01 [g]	3,898	298	7.1%	4,196
2001-02 [g]	6,889	354	4.9%	7,243
2002-03 [g]	4,304	78	1.8%	4,382
2003-04 [g]	11,844	280	2.3%	12,124
2004-05 [g]	3,656	30	0.8%	3,686
2005-06 [g]	2,014	19	0.9%	2,033
AVERAGE	**4,496**	**339**	**8.7%**	**4,847**
'92-93 to '05-06 AVG	**3,712**	**175**	**5.3%**	**3,887**
Mesh Study Average	**5,434**	**177**	**3.0%**	**5,611**

[a] Catch with round haul gear from Tomales Bay.

[b] Catch includes the use of round haul and gill net gear types, and herring caught from both Tomales Bay and Bodega Bay.

[c] Catch is by gill net only, includes catch from Tomales and Bodega Bay. Use of round haul gear prohibited since 1978-79 season, in Tomales Bay and Bodega Bay.

[d] Catch is by gill net only with minimum mesh size of 2-in., includes catch from Bodega Bay.

[e] Tomales Bay fishery is closed. Bodega Bay fishery remains open with gill nets, minimum mesh size of 2-in.

[f] Bodega Bay fishery is closed and Tomales Bay fishery is re-opened with gill nets with a minimum mesh size of 2 1/8–in.

[g] Bodega Bay fishery remains closed. Gill nets with a minimum mesh size of 2-in. are allowed during the gill net mesh study, in progress. The mesh study is being conducted to evaluate the use of a minimum mesh size of 2-in. gill nets on the Tomales Bay herring population.

[1] Spawning ground escapement survey not conducted to generate the spawning biomass.

[2] Spawning biomass estimated by cohort analysis for this season.

Commercial catch and independent research population data collected for the 2005-06 season were insufficient to characterize the Tomales Bay fishery and spawning population. Small commercial landings occurred on one day, from only one spawning wave, and were inadequate to provide comparisons with previous seasons. Research catch data for this season were also limited because of a reduction in sampling effort due to a lack of Department personnel. Due to these factors, only limited assessment was made of the 2005-06 spawning biomass and commercial fishery. Based upon the historical data, it is apparent that the Tomales Bay herring population is both dynamic and resilient. These data also suggest that ecological conditions play a far greater role in the fluctuation of the Tomales Bay population than the harvest by the commercial fishery. There is a predicted continuation of a weak La Niña, i.e., cool water event, which often is considered to be beneficial for a cold-water species like herring. As the oceanic conditions improve there is the potential for a greater return of herring to Tomales Bay next season.

3.4.1. Tomales Bay Experimental Mesh Size Study

After six consecutive seasons the Department is discontinuing the experimental mesh size study for the Tomales Bay fishery. This study allowed permittees to use a gill net mesh size of 2-in., which is smaller than the 2 1/8-in. mesh required by regulation. The Department has evaluated the effects of using 2-in. mesh on the age classes caught by the commercial fleet to ensure that the younger fish (≤ 3-year-olds) are not significantly impacted, thus potentially causing the fishery to become unsustainable. It is not surprising, given the smaller mesh size, that commercial catch data show an increased take (203% from pre-mesh study levels, 1993-94 to 1999-2000 seasons) of 3-year-old herring during the mesh study period, however, the take of 3-year-olds has remained at higher than expected levels. The expectation that the Tomales Bay age structure was primarily older fish (≥ 4-year-olds) was based on population assessments prior to the use of 2-in. mesh beginning in the 2000-01 season.

From 1993-94 to1999-2000 (prior to the mesh study), 3-year-old herring

averaged approximately seven percent of the commercial harvest in Tomales Bay. During the mesh study (2000-01 to the present), 3-year-olds averaged 25 percent of the commercial catch. The increase in the percentage of 3-year-old herring taken by the fishery during the mesh study is a function of a number of factors including: large numbers of 3-year-olds in the spawning population (Table 3.4); below-average numbers of 5-year-old and older herring; and the expected shift in size selectivity to include smaller younger herring, due to the gill net mesh size reduction to 2-in. It is unlikely that the use of 2-in. mesh gill nets in Tomales Bay has had a detrimental effect on the age structure of the spawning population due to the low harvest rate (average 3.0 percent) during the study period. However, the trend of increased harvest of 3-year-old herring is cause for concern. Alleviating some of the concern is the dramatic increase in the proportion of younger fish in the population during the mesh study (435% increase in the average estimated number of 2- and 3-year-old herring from pre-mesh study period, 1993-94 to 1999-00 seasons).

Length data gathered since the commercial fishery was re-opened in 1992-93 season have shown that the mean length of commercially caught herring (191 mm) has changed very little from the pre-mesh study period (192 mm) to the mesh study (189 mm). The slight differences in means could be attributed to both the change in Tomales Bay stocks age structure and changes in mesh size. The selectivity of gill nets is a function of mesh size and the size distribution of herring present at the time the nets are fished. The school composition and timing of spawning runs greatly affect the age compositions of the commercial catch. Early spawning runs are composed of larger herring which are typically older fish, and later runs are usually dominated by smaller younger fish. During the mesh study period much of the spawning biomass was not catchable because spawning occurred prior to the commercial season. The fish in these earlier schools are often the larger herring. The weather is another factor related to timing that can affect the commercial industry ability to target larger herring. Weather events sometimes prevent fishermen from fishing on earlier schools dominated by larger herring. Therefore fishing effort is shifted to later schools that are usually dominated by smaller fish.

Table 3.4 Estimated Numbers (x 1,000) of Herring-at-Age in the Tomales Bay Spawning Population, 1993 to present																		
Age and Percent Composition																		
Season	1	%	2	%	3	%	4	%	5	%	6	%	7	%	8	%	9	%	Total
93-94	0	0	567	2.8	3,329	16.7	6,021	30.1	3,329	16.7	5,171	25.9	1,062	5.3	425	2.1	71	0.4	19,974
94-95	0	0	4,446	13.9	10,209	32.0	4,281	13.4	3,293	10.3	5,846	18.3	2,717	8.5	988	3.1	165	0.5	31,945
95-96	0	0	1,000	5.6	1,643	9.2	7,287	40.6	5,930	33.1	1,072	6.0	214	1.2	786	4.4	0	0	17,932
96-97	0	0	117	1.0	2,225	18.4	4,625	38.2	4,098	33.8	820	6.8	234	1.9	0	0	0	0	12,118
97-98																			
98-99	0	0	11,655	25.1	14,127	30.5	14,598	31.5	4,827	10.4	1,177	2.5	0	0	0	0	0	0	46,383
99-00	0	0	487	2.2	5,606	25.4	10,603	48.1	4,753	21.5	244	1.1	366	1.7	0	0	0	0	22,059
00-01	0	0	6,983	16.7	17,642	42.1	15,437	36.8	1,838	4.4	0	0	0	0	0	0	0	0	41,900
01-02	0	0	19,379	25.3	35,776	46.8	17,060	22.3	4,306	5.6	0	0	0	0	0	0	0	0	76,521
02-03	0	0	15,113	29.3	22,589	43.8	11,613	22.5	2,148	4.2	80	0.2	0	0	0	0	0	0	51,542
03-04	0	0	45,193	31.7	55,565	39.0	26,548	18.6	11,483	8.1	2,593	1.8	1,235	0.9	0	0	0	0	142,616
04-05	0	0	10,560	25.0	18,170	43.1	9,498	22.5	3,481	8.3	472	0	0	0	0	0	0	0	42,181
05-06																			
Mean	0	0	10,500	16.2	16,989	31.5	11,597	29.5	4,499	14.2	1,588	5.7	530	1.8	200	0.9	21	0.1	45,925
Note: 1997-98 and 2005-06 seasons not included due insufficient data set for expansion																			

Another possible cause for the increased take of 3 year-old herring is that fishermen are retrieving there gear faster. Due to increased predation by marine mammals fishermen tend to have shorter sets and retrieve their gear faster to reduce predation of catch and gear damage by marine mammals. There is speculation that faster sets and gear retrieval may prevent a portion of smaller herring that would normally escape the gill net to be retained.

Despite an increased take of 3-year- old herring during the mesh study period, the average exploitation rate from the estimated Tomales Bay population for both the pre-mesh study period (1993-94 to 1999-00) and mesh study period was the same (0.4 percent). The average percentage of 3-year-olds commercially taken from the estimated number of 3 year-olds in the population is less during the mesh study period (0.8 percent) than the pre-mesh study period (2.2 percent). It is unknown why the Tomales Bay spawning stock structure has changed to include more young fish (2- and 3-year-old herring), and the persistent lack of older fish (≥ 6 year-old herring) in the population. However, it appears that the commercial exploitation of the Tomales Bay herring is not a major factor. Little is known about the offshore portion of the herring life history, and other factors (e.g., predation and/or prey abundance) maybe responsible for recent trends observed in the population.

Based on the data collected from the 2-inch experimental mesh study, the Department has determined that the use of 2 inch mesh gill nets has minimal effects on the Tomales Bay herring stock and its continued use is consistent with the Department goal of a conservative exploitation rate. If the Tomales Bay stock should continue rebuilding, the commercial catch composition may shift to older age classes if they persist in the population. Therefore, the Department is proposing that the mesh size in Tomales Bay be set at a minimum of two-inches and a maximum of 2 ½ inches.

3.5 Status of the Humboldt Bay and Crescent City Spawning Populations

Herring appear to spawn almost exclusively on the vast eelgrass beds found in both the North and South Bays of Humboldt Bay. During a typical spawn event, herring schools may deposit eggs in low density over 300 acres of eelgrass. The spawning biomass estimate for the 2005-06 season is 124 tons, down 50 tons from last season's estimate of 174 tons. The spawning biomass this season represents only 31 percent of the 10-year average of 402 tons and is the lowest estimate recorded from seasons when spawn assessments were conducted in Humboldt Bay. There were three separate spawn events found in the bay this year. The first spawn detected occurred in the North Bay on January 7th and was estimated at 4 tons. The next spawn took place between January 28 and February 6 in the South Bay and was estimated at approximately 57 tons. The last spawn detected this season occurred in the North Bay on February 8th and was estimated at 63 tons.

There was no fishing effort this season by Humboldt Bay permittees. For the last five seasons when fishing occurred, the average total landings per year was close to 20 tons with a range of just below 0.6 tons in 2003-04 to 61.2 tons in 2000-01. For the last three seasons biomass estimates were far below average; however, the exploitation rate during 2002-03 and 2003-04 seasons remained below one percent with no exploitation occurring 2005-06. The average yearly biomass estimate from the last six spawn assessment surveys conducted since the 2000-01 season is 464 tons. A 60-ton quota based on this average would result in a 13 percent exploitation rate, which is considered a conservative rate of harvest.

During the winter of 2006-2006 the Department of Fish and Game, University of California Sea Grant, Humboldt State University, and Humboldt Bay Harbor District completed the fifth and final year of a study monitoring the population characteristics of eelgrass in Humboldt Bay. Eleven sites in the north, central and the south regions of Humboldt Bay were surveyed. Above-ground eelgrass biomass (fresh weight) for winter 2005-06 had a mean of 0.47 kg/m^2 (range 0.06-0.66 kg/m^2), which is a 29 percent decrease from the winter 2004-05 mean of 0.61 kg/m^2 (range 0.17-1.58 kg/m^2). These data are essential for herring research and has greatly improved the accuracy of the season's spawning biomass estimate.

Spawning ground surveys and commercial fishery assessments were not conducted in the Crescent City area for the 2005-06 season. Although two permits are active in Crescent City, no fishing effort has taken place in Crescent City for the past four seasons. The Department does not plan to conduct spawning ground surveys and commercial fishery assessments in the Crescent City area for the 2006-07 season. The 30-year average catch of 22 tons per year for Crescent City permittees is far below the set 30-ton quota for this fishery.